A. PROJECT MANAGMENT
A1. Title and Approval Sheet

U.S. Environmental Protection Agency
Office of Research and Development
Center for Environmental Measurement and Modeling
Immediate Office

Click here to enter text.

Quality Assurance Project Plan

Title: Analysis of Seasonal Change on Grassland Smoke Emissions: Spring and Fall 2021

QA Category: ☐ A ☒ B

QAPP was Developed: ☒ Intramurally ☒ Extramurally: University of Dayton Research Institute

QAPP Accessibility: QAPPs will be made internally accessible via the [ORD QAPP intranet site] upon final approval *unless the following statement is selected*.
☒ I do NOT want this QAPP internally shared and accessible on the ORD intranet site.

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QAPP Revision History

QAPP ID Number	Prepared By	Date of Revision	Description of Change
J-IO-0030862-QP-1-5	Brian Gullett, Johanna Aurell	03/17/2021	Issuance

A3. Acronyms & Abbreviations

AED	Automated External Defibrillator
BC	Black carbon
CEM	Continuous emissions monitor
CEMM	Center for Environmental Measurement and Modeling
CFR	Code of Federal Regulation
CPHEA	Center for Public Health and Environmental Assessment
CO	Carbon monoxide
CO_2	Carbon dioxide
CoC	Chain of custody
CPR	Cardiopulmonary resuscitation
BC	Black Carbon
DAQ	Data acquisition system
DAS	Data acquisition system
DoD	Department of Defense
DQI	Data quality indicators
DGR	Dangerous Goods Regulations
EC	Elemental carbon
EES	Energy and Environmental Sciences
EF	Emission factor
EPA	Environmental Protection Agency
fc	Carbon fraction
FEPS	Fire emission production simulator
FR	Fast response
GPS	Global positioning system
HAZWOPER	Hazardous Waste Operations and Emergency Response
IATA	International Air Transport Association
ICP-MS	Inductively Coupled Plasma – Mass Spectrometry
ID	Identification
IR	Infrared
KDHE	Kansas Department of Health and Environment
KPBS	Konza Prairie Biological Station
L/min	Liter per minute
NA	Not applicable
NDIR	Non-dispersive infrared
NELAP	National Environmental Laboratory Accreditation Program
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute for Standards and Technology
NO	Nitric oxide

NO_2	Nitrogen dioxide
O_3	Ozone
OC	Organic carbon
ORD	Office of Research and Development
PCF	Photometric calibration factor
PDF	Portable document format
PED	Power & Energy Division
PEM	Personal environmental monitor
PI	Principal investigator
PM	Particulate matter
PM10	Particulate matter equal to and less than 10 µm
PM2.5	Particulate matter equal to and less than 2.5 µm
PM4	Particulate matter equal to and less than 4 µm
POC	Point of contact
POM	Personal ozone monitor
ppm	parts per million
QA	Quality Assurance
QAPP	Quality assurance project plan
QC	Quality Control
RARE	Regional and Applied Research Effort
RH	Relative Humidity
RMS	Root mean square
RPD	Relative percent difference
RSD	Relative Standard Deviation
RTP	Research Triangle Park
SD	Secure digital
SHEM	Safety, Health, and Environmental Management
TBD	To be determined
TC	Total carbon
THC	Total hydrocarbon
TOA	Thermo optical analysis
TPNP	Tallgrass Prairie Nature Preserve
TSP	Total suspended particles
UAS	Unmanned aircraft systems
UDRI	University of Dayton Research Institute
UGV	Unmanned ground vehicle
µm	micrometer
U.S.	United States
USA	United States of America
USB	Universal Serial Bus

USGS	US Geological Survey
UV	Ultraviolet
VOC	Volatile organic compounds
XRF	X-Ray Fluorescence

A4. Distribution List

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* For informational purpose only.

A5. Project Organization

This work is being conducted for two separate efforts. The main project is a Regional and Applied Research Effort (RARE) project with EPA Region 7. The second effort is an interagency agreement (RW-014-92517701) funded by the U.S. Geological Survey (USGS). The organizational chart for EPA's sampling team is shown in Figure A5.1 and the contact information for each team member is shown in Table A5.1

Dr. Brian Gullett (U.S. EPA) will serve as the lead principal investigator (PI) on the projects. He is responsible for the overall conduct and output of the emissions sampling portions of the projects. Dr. Gullett is responsible for EPA personnel logistics, the project QAPP, and the analysis and dissemination of the results.

Ms. Libby Nessley (U.S. EPA) is the Quality Assurance Manager and responsible for processing QA review of project plans and products generated for this project.

Dr. Amara Holder (U.S. EPA) is an expert on particle physical, chemical, and optical properties.

Dr. Johanna Aurell (UDRI) is the chief operator of EPA's emission sampling system and is responsible for EPA's sampling instruments. Dr. Aurell will conduct equipment checks prior to shipment including pump flows and gas calibration checks. She will be the lead sample and data custodian and will be responsible for downloading, storing, and reducing the instrument data for analysis. She will also be responsible for calculating emission factors.

Mr. Filimon Kiros (UDRI) will serve as sampling assistant to Dr. Aurell.

Mr. William Mitchell (U.S. EPA) is the chief electronics engineer and will be responsible for the electronic functioning of the sampling systems, called the "Flyer" and "Kolibri", their computers and transmission/receiving systems.

Mr. Dale Greenwell (U.S. EPA) is responsible for equipment logistics.

Dr. David Damby (USGS) will serve as a Co-PI on the USGS project. Dr. Damby is taking particle samples collected by EPA for analyses at USGS.

Dr. Ian Gilmour (U.S. EPA) is a participant on the USGS-funded interagency agreement. Dr. Gilmour will receive particle samples for toxicological studies. His studies are covered under a separate QAPP.

Mr. Joe Adams (USGS) is the USGS UAS pilot in command.

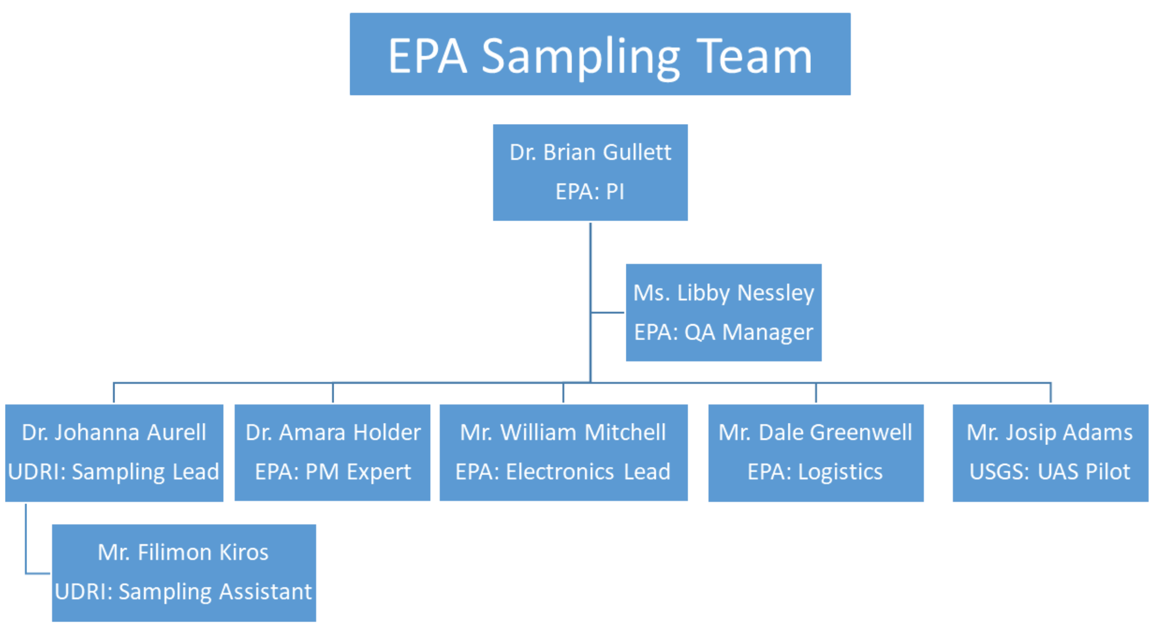

Figure A5.1: Project Organization.

Table A5.1: Project Personnel and Contact Information.

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A6. Problem Definition and Background

A6.1. Introduction

The primary portion of this work is a continuation of a Regional Applied Research Effort, Project #: 1763, entitled "Grassland Smoke Emission Measurement Supporting Multi-Modeling Framework Simulation of Rangeland Burning Practices for the Kansas Flint Hills". Between March and November of 2017 and April of 2019, seventeen field burns were sampled for emissions at Konza Prairie Biological Station (KPBS), Tallgrass Prairie Nature Preserve (TPNP), and Elk County Youngmeyer Ranch including fields with prescribed burn return intervals of 1 to 4 years and biomass density of 5.29 to 6.96 MT/ha. Spring (n=11) and fall (n=2) burns were sampled at KPBS, spring in Elk County (n=1), and fall burns only (n=3) at TPNP.

This work was initiated to calculate more accurate and condition-specific emission factors for the Flint Hills' annual rangeland burning that could be used to better predict smoke and air quality impacts. The improved emission factors are important in supporting better performing air pollution dispersion modeling and will allow policy makers to better balance public health concerns with the agricultural viability of the Flint Hills. A secondary objective was to determine the effect of seasonal variation of emission factors from the typical springtime burns. Data from these experiments will be provided to the Kansas Department of Health and Environment (KDHE) to support their user-friendly air quality modeling and visualization tool set available on KSFIRE.ORG as well as ORD's VELMA model (Bob McKane).

Since 2017 a comprehensive array of emissions from prescribed grassland burns were sampled using a variety of aerial- and ground-based means. Emission instruments designed by ORD were lofted using a tethered aerostat or were placed on ground-mobile samplers to monitor and sample emissions. Field burning was opportunistic, at multiple sites, leading to an array of sites, burn return intervals, land use, and seasons. Given the limited number of samples and the incomparability of sites (moisture, burn year, land use, etc.), discerning seasonal distinctions with the current emission data is not possible.

A follow-on effort funded was proposed to remedy this seasonal emission factor gap. While the existing data are certainly sufficient to express the relevant range of emission factors and the data quality is good and representative of the range of emission factors, there was not enough control over selection of test conditions to be able to confidently make a season conclusion. The ad hoc nature of the testing limits conclusions relating to seasonal or return-year emissions. To obtain the data necessary to complete the seasonal analysis, the team required a series of test plots in at least one location that could be burned over the two seasons. Such an array of ten plots has been demarcated at the KPBS, operated by Kansas State University. Sampling will be completed using instruments borne on a mobile, radio-controlled unmanned ground vehicle (UGV) and Unmanned Aircraft Systems (UAS) flights, the latter provided through a complimentary contribution from the USGS out of Denver.

The second project served under this sampling effort is a grant from the USGS entitled "Determination of Forest Fire Intensity Effects on Emissions and Particulate Matter Characteristics Using an Unmanned Multicopter." The objective of this effort is to deploy a UAS-based emission sampler that will link meta-data on the burn with emissions composition/characterization and subsequent cardiopulmonary toxicity effects. Samples will include real-time constituents and cumulative PM solids for subsequent analysis.

A6.2. Objective

The research objective of this effort is to use plume sampling technologies and a set of tall grass plots located in the Kansas Flint Hills to calculate more accurate and condition-specific emission factors for tall prairie grasses that will be used to better predict optimal times to burn. Data from these experiments will be used to contribute to the validation or correction of current FEPS models used in prairie regimes such as the current collaborative effort between EPA Region 7, EPA's ORD and the State of Kansas and Kansas State University in the development of a user-friendly air quality modeling and visualization tool set which includes an air modeling component.

The objective for the USGS effort is to determine the ability of UAS-based instrumentation to determine emission factors from wildland fires, to gather sample for analyses by USGS, and to determine toxicological respiratory properties of the smoke.

A7. Project Description

A7.1. Project Site Location

The testing will be conducted at KPBS, KA. An additional test site close to Konza may also be used and will be determined upon arrival at Konza. All sites are weather dependent as well as contingent upon the site's fire crew availability and operating schedules.

A7.2. Project Schedule

The project timeline and schedule with start and completion dates are shown in Table A7.1. The dates and timeline are subject to change depending on the evolution of COVID-19 restrictions on travelling and weather conditions.

Table A7.1: Project Schedule.

Date	Activity
March 21, 2021	Part of the EPA Team departs RTP by car
March 22, 2021	Part of the EPA Team departs RTP by air, entire team arrives at Konza
March 23, 2021	Equipment setup and first day of sampling
March 24, 2021	Sampling continues
March 25	Sampling concludes
March 26, 2021	EPA Team departs Konza, part of EPA Team arrives at RTP
March 27, 2021	Part of EPA Team arrives at RTP
May 15, 2021	Sample analysis starts
July 2, 2021	Sample analysis complete
July 30, 2021	Status report

A8. Quality Objectives and Criteria for Measurement Data

Table A8.1 list the data quality indicators (DQI) for this study. Bias for each pollutant sampled are described in Section B5.

Table A8.1: Data Quality Indicators.

DQI	QC Activities	Performance Goal
Precision	Duplicate or replicate samples will be collected for each test location.	RSD/RPD ±50%
Bias	Use of calibration gases, blank reference filters	Varies depending on the pollutant, described in Section B5.
Representativeness	Multiple samples will be collected from each test location to obtain a range of data.	The same sampling instruments will be used for each test location. Stop testing when CO_2 is 20 ppm above background levels for all collected samples.
Comparability	Data will be compared to previous studies.	The instruments used in this study have previously been used in other emission studies from combustion sources.
Completeness	Evaluate percent of samples collected.	We expect to complete > 90% of the tests and sample collection.
Sensitivity	Background sampling	At least three times above background levels.

RSD = relative standard deviation. RPD = relative percent difference.

A9. Special Training/Certifications

EPA on-site sampling team personnel include Drs. Gullett, Aurell and Holder, and Messrs. Kiros, Greenwell, and Mitchell. All on-site EPA team personnel will have completed EPA's Safety, Health, and Environmental Management (SHEM) and field safety trainings. The EPA team have also completed EPA's respiratory training and are medically cleared and fit tested to use half-face respirators. Dr. Gullett and Mr. Greenwell are both First Aid and CPR/AED certified. The EPA team will bring an AED to the site. Both Drs. Gullett and Aurell are HAZWOPER certified. Dr. Aurell is certified to ship dangerous goods according to IATA DGR Section 1.5 and 49 CFR 172.704.

A10. Documents and Records

Dr. Gullett will be responsible for distributing the most recently approved version of this QAPP to the people listed on the distribution list in Section A4 of this QAPP. Dr. Aurell will ensure that sufficient Sample Record Forms, Chain of Custody (CoC) Forms, and sample labels are available. Table A10.1 shows the documents, records, and location of the documents generated in this study.

Table A10.1: Summary of Project Documents and Records

Document	Records	Location
Field notebooks	Calibration date and time, and test notes	EPA Lab E366
Sample record form	One form for each test scenario	L:\Lab\NRMRL_Aurell\Tallgrass and Konza Prairie\2021\CoC
Chain of custody	One form for each pollutant	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\CoC
Sample labels	One label for each sample	On each sample bag
LICOR-820 raw data files	One file for each test	L:\Lab\NRMRL_Aurell Tallgrass and Konza Prairie\2021\LICOR\RawData
Kolibri raw data files	One file for each test day	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\KolibriData\RawData
Flyer raw data files	One file for each test	L:\Lab\NRMRL_Aurell Tallgrass and Konza Prairie\2021\FlyerData\RawData
Instrumentation raw data files	One file for each instrument and test day	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\XX
Laboratory results	One file for each pollutant	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\YY
Kolibri processed data files	Calculates carbon concentration and volume collected for each sample	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\KolibriData\ProcessedData
Flyer processed data files	Calculates carbon concentration and volume collected for each sample	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\FlyerData\ProcessedData
LICOR-820 processed data files	One file for each test	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\LICOR\ProcessedData
Emission factor data files	Calculates emission factors for each pollutant	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\YY
Status/Final reports	Documents activities and findings	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\Final Report
Presentations	Summarize activities and findings	L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021\Presentations

XX = Instrument such as DustTrak. YY = Pollutant such as PM.

A10.1. Data Storage

Laboratory data will be transferred from the instruments' data loggers to external hard drives via a laptop computer with a universal serial bus (USB) port. Electronic data and pictures will be posted in the L:\Lab\NRMRL_Aurell\Tallgrass and Konza Prairie\2021 folder on the EPA network drive as they are generated or received.

B. DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

B1.1. Test Plan

The KPBS will establish candidate field sites for emission sampling (Figure B1.1). Sites will be classified based on biomass and fuel density characteristics of:

- Grass (non-woody) predominant;
- Woody (cedar/dogwoods) predominant;
- High density (long duration since last burn);
- Low density (recent burn).

The host site will conduct the burns. On each site, 1 m x 1 m "Clip" plots will be established for pre- and post-burn species and biomass density.

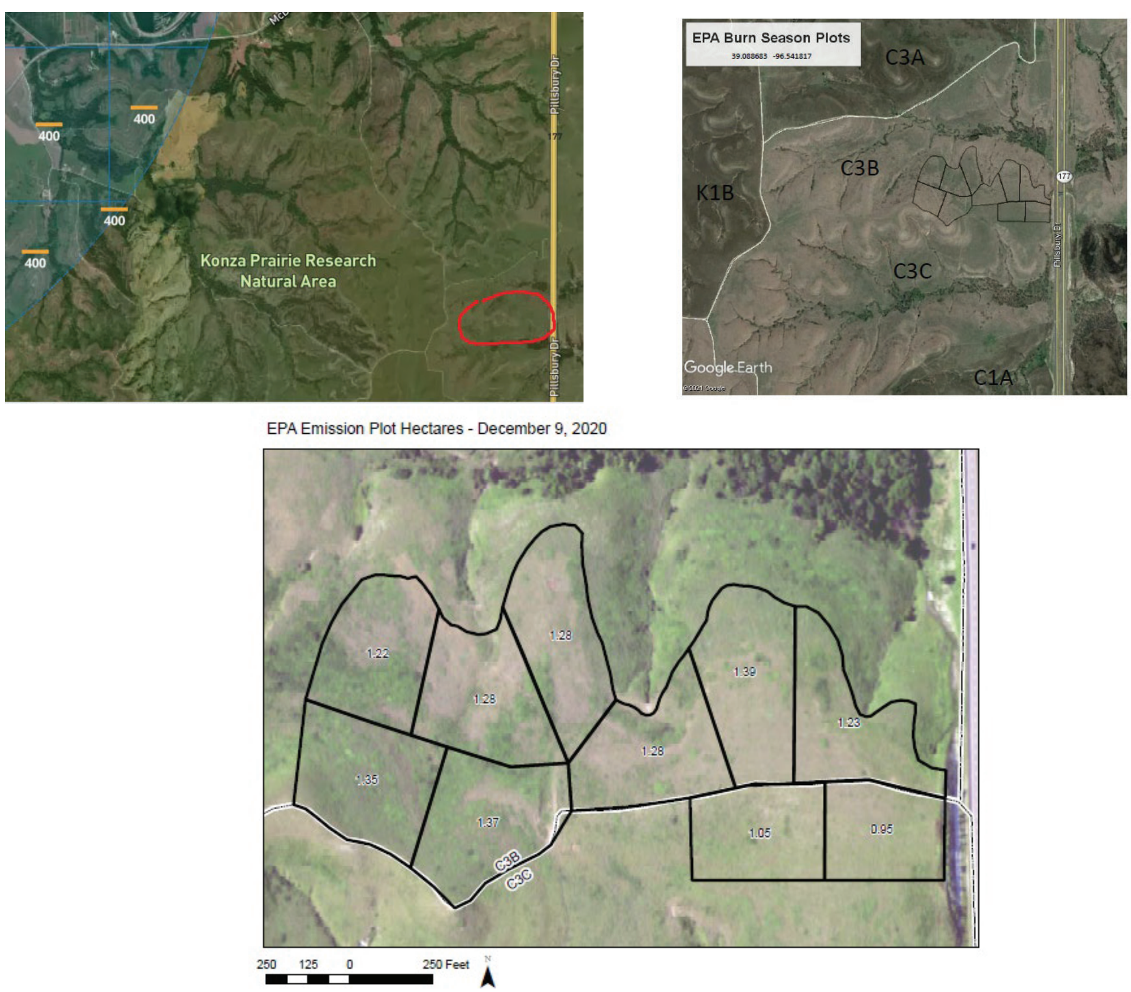


Figure B1.1. Field Sites at Konza Prairie.

B1.2. Biomass Sampling

B.1.2.1 Clip Plots

Within each test field, 1 m × 1 m, biomass-representative clip plots will be established for pre-burn biomass sampling to determine representative fuel moisture, species, and biomass loading prior to and after burning (Figure B1.2). The biomass from the clip plot will be clipped or cut, speciated into main groups, weighed by species, and stored in paper bags. Each bag will be tagged with a label which will include bag and plot number. Additional information will be added to field notebook referring to bag number and plot number. The clip plot locations will be surveyed after the burn to determine the combustible weight loss if residual unburned biomass is observed.

Figure B1.2: Example of Clip Plots.

B.1.2.2 Fuel Moisture

Biomass obtained from the clip plots will be measured for moisture content. A collected biomass sample will first be weighed at KPBS station, dried overnight, and then weighed again. This procedure will enable us to obtain the moisture content as burned. The moisture content will be following procedures described in QAPP J-IO-0032756-QP-1-0 Section B2.8; as such, those measurements are not included in this QAPP.

B1.3. Measured Parameters

The measured parameters at each test field are shown in Table B1.1.

Table B1.1: Measured Parameters.

Measurement
GPS
Clip plot density
Clip plot moisture
Met: RH
Met: Temperature
Met: Wind Velocity
CO_2
CO
NO
NO_2
THC
O_3
$PM_{2.5}$
PM_{10}
PM Elemental Composition
PM by size
TC/OC/EC
VOC
Black Carbon, UVPM
Relative Humidity
Plume Temperature

B1.4. Sampling Approach

B.1.4.1 Sampling Platforms

Two different sampling platforms will be used for this effort (Figure B1.3):

- EPA's UGV
- USGS's UAS (Matric 600 DJI)

Figure B1.3: Sampling Platforms A) UAS and B) UGV.

B.1.4.2 Flight Operations

Aerial sampling will be conducted by a UAS operated by USGS at a height of less than 400 feet. USGS's UAS is a DJI Matrice M600 which is a 6-rotor (hexacopter) with a 9.1 kg weight and a 15.1 kg maximum acceptable gross take-off weight. Its expected maximum loaded flight time is 15-20 min. It is controlled automatically or by pilot-in-command modes and provides the operator a GPS display screen of location in real time with a 900 MHz telemetry system. The M600 has a triple redundant inertial measurement unit and GPS and a return to base function at a preset battery charge.

B.1.4.3 Sampling Equipment

Two different types of sampling packages will be used: the "Flyer" and the "Kolibri" (Figure B1.4). The Flyer system is a 22 kg battery-powered, remotely controlled pollution sampler that was developed in EPA laboratories and modified extensively since its 2010 use in the Gulf [1]. The Kolibri is a ~3 kg system that operates similarly to the Flyer but with less sampling pumps, also developed in EPA's laboratories.

For this effort, the Flyer components will be configured to sample CO, CO_2, $PM_{2.5}$, and Total PM. There are two configurations of the Kolibri primarily relating to the different sizes of the pumps needed for specific analytes. There is one model of the smaller unit, "Alvis," and duplicate models for the slightly lager configuration for redundancy, "Forseti" and "Balder". For this effort, the Kolibri components will be configured to sample CO, CO_2, NO, NO_2, THC, TC/OC/EC and $PM_{2.5}$. The sampling package's components and total weight are described in Table B1.2.

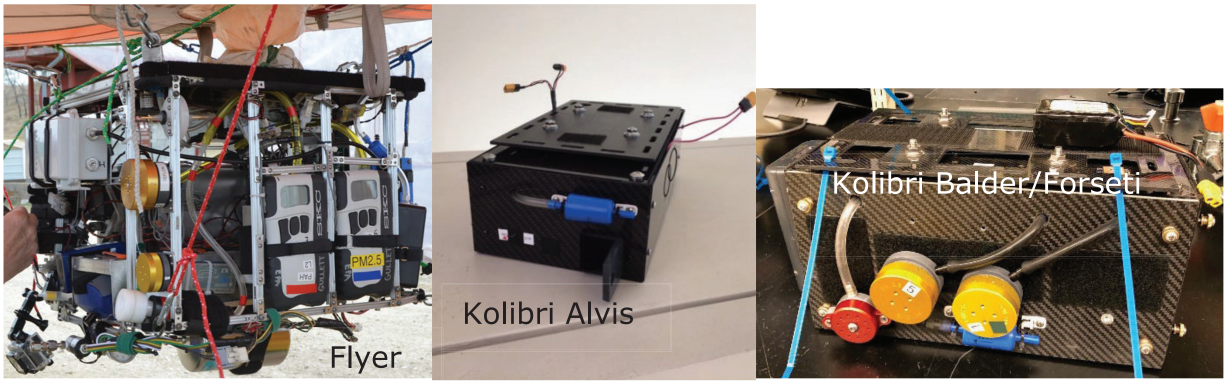


Figure B1.4: Flyer and Kolibri Sampling Instrument Packages.

Table B1.2: Sampling Platform and Designated Sampling Package.

Sampling Platform	Sampling Package	Components	Weight (gram)
UAS	Kolibri: Forseti	CO_2, CO, NO, NO_2, $PM_{2.5}$, RH, Temperature, TC/OC/EC, VOC, MA200, SidePak	4030 g total weight, 2988 g no MA200 or SideTrak, 3370 g with MA200
UAS	Kolibri: Alvis	CO_2, CO, NO, THC, $PM_{2.5}$, Temperature, DustTrak DRX 8534	2392 g no DustTrak
UAS	Kolibri: Balder	CO_2, CO, NO, NO_2, 2×$PM_{2.5}$, 2×TC/OC/EC, RH, Temperature	4470 g total weight, 3376 g no MA200 or SideTrak, 3810 g with MA200
UGV	Flyer: Orville	CO_2, CO, $PM_{2.5}$, PM_{10}, Total PM, Temperature, DustTrak DRX 8533, O_3, MA350	~22 kg

B2. Sampling Methods

Table B2.1 shows a summary of the measured parameters, sampling methods, and instrumentation to be used in the study. The $PM_{2.5}$ 47 mm Teflon filter samples will be used for toxicity testing. This testing will be undertaken by Dr. Ian Gilmour ORD/CPHEA and is not part of this QAPP but is described in QAPP NHEERL/EPHD/CIB/Ig/2015-001-04. Only the collection of the inhalable PM for Dr. Gilmour from the prescribed burning is included in his QAPP. The total PM will also be used for chemical analysis by USGS and so is not part of this QAPP.

Table B2.1: Measured Parameters, Sampling Instruments, Methods, and Flow/Sampling Rates.

Measured Parameter	Instrument/ Equipment	Method	Flow rate/ Sampling Rate
CO_2	LICOR-820, CO_2 Engine® K30	NDIR	0.5-1.0 L/min, 1 Hz
CO	EC4-500-CO	Electrochemical cell	0.5 L/min, 1 Hz
NO	NO-D4	Electrochemical cell	0.5 L/min, 1 Hz
NO_2	NO2-D4	Electrochemical cell	0.5 L/min, 1 Hz
THC	MiniPID2	Electrochemical cell	0.5 L/min, 1 Hz
O_3	Personal Ozone Monitor™	By UV absorption	0.8 L/min, 0.1 or 0.5 Hz
$PM_{2.5}$	SKC Personal Environmental Monitor (PEM) Impactor	37 mm Teflon filter/ gravimetric	10 L/min, Batch
$PM_{2.5}$ and elemental composition	SKC IMPACT Sampler	47 mm Teflon filter/ Gravimetric/X-ray fluorescence/Inductively Coupled Plasma – Mass Spectrometry	10 L/min, Batch
PM_{10} and elemental composition	SKC IMPACT Sampler	47 mm Teflon filter/ gravimetric/X-ray fluorescence/Inductively Coupled Plasma – Mass Spectrometry	10 L/min, Batch
Total PM	Windjammer blower	Teflon filter 20.3×25.4 cm	~1200 L/min, Batch
PM by size	DustTrak DRX 8534/8533	90° Light scattering	3 L/min, 1 Hz
PM by size	SidePak™ AM520	90° Light scattering	1.54 L/min, 1 Hz
TC/OC/EC	SKC Personal Modular Impactor (PMI)	Quartz filter/thermal-optical analyses	3 L/min, Batch
VOC	CarboTrap 300	Sorbent tube/thermal desorption	0.200 L/min, Batch
Black Carbon	MA200/MA350, AE51	Filter-based light attenuation	150 mL/min, 1 Hz

B.2.1.1 Sampling Platforms and Sampling Package/Equipment/Instruments

Table B2.2 shows the sampling packages and sampling instruments designated for each sampling platform.

Table B2.2: Sampling Equipment/Instrumentation used for each Sampling Package and Sampling Platform.

Sampling Platform	Sampling Package	Sampling Instruments	Computer/Pad
UAS	Kolibri: Forseti	CO, CO_2-K30, NO, NO_2, $PM_{2.5}$ - PEM, TC - PMI, VOC, MA200, SidePak, Temperature, RH	Dell pad #2
UAS	Kolibri: Alvis	CO, CO_2-K30, THC, $PM_{2.5}$ – PEM, DustTrak DRX 8533, Temperature, AE51	Toughpad #1 and #2
UAS	Kolibri: Balder	CO, CO_2-K30, NO, NO_2, $PM_{2.5}$ – PEM, TC – PMI, SidePak, Temperature, RH, AE51	Dell pad #1
UGV	Flyer: Orville	CO, CO_2-LICOR, DustTrak DRX 8533/8534, Temperature, $PM_{2.5}$ & PM_{10} – IMPACT sampler, Total PM – blower	Toughbook #2

B2.2. CO_2 Measurements

The Kolibri system uses a CO_2 Engine® K30 Fast Response (FR) (SenseAir, Delsbo, Sweden) to measure CO_2 concentration by means of non-dispersive infrared absorption (NDIR). Sensor output voltage is linear from 0 to approximately 7900 ppmv. The response time (t_{95}) is less than 10 seconds and measurement is accurate within 5% error. The sensor can operate at temperature ranges -10-40ºC and RH 0-95%. In the field, a particulate filter will precede the sensor's optical lens and CO_2 background samples will be taken daily prior to sampling. The CO_2 Engine® K30 FR will be calibrated for CO_2 on a daily basis in accordance with EPA Method 3A [2]. Calibration details are described in Section B7. If the calibration is outside the acceptance criteria (Table B2.3) the first corrective action will be to re-calibrated the CO_2 Engine® K30 FR and the second step is to replace it with another CO_2 Engine® K30 FR. Data will be recorded on the Teensy, a USB-based microcontroller board using an Arduino-generated data program.

The Flyer system uses a LICOR-820 to measure CO_2 which is a NDIR based instrument (LI-COR Biosciences, Lincoln, USA). These units are configured with a 14 cm optical bench, giving it an analytical range of 0-20,000 ppm with an accuracy specification of less than 3% of reading. A particulate filter precedes the optical lens. The LI-820 is calibrated for CO_2 on a daily basis in accordance with EPA Method 3A [2]. Calibration details are described in Section B7. If the calibration is outside the acceptance criteria (Table B2.3) the first corrective action will be to re-calibrated the LI-820 and the second step is to replace it with another LI-820. The LI-820 CO_2 concentration will be recorded on the onboard Flyer computer using LabView-generated data program. The data will be transferred from the Flyer computer to an external hard drive at the end of each test day.

Table B2.3: CO_2 Measurements.

Target Compound	Measurement	Flow rate/ Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
CO_2	K30/NDIR	0.5-1.0 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or switch to backup K30	Data stored on external hard drive
CO_2	LICOR-820/NDIR	0.5-1.0 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or switch to backup LICOR	Data stored on external hard drive

B2.3. CO Measurements

The CO sensor (e2V EC4-500-CO) is an electrochemical gas sensor (SGX Sensortech, Essex, United Kingdom) which measures CO concentration by means of an electrochemical cell through CO oxidation and changing impedance. The e2V CO sensor has a CO detection range of 1-500 ppm with resolution of 1 ppm and sensitivity of 55-85 nA/ppm. The temperature and RH operating range is -20 to +50°C and 15 to 90% RH, respectively. The response time is less than 30 seconds. Output is non-linear from 0 to 500 ppm. Calibration details are described in Section B7.

Table B2.4: CO Measurements.

Target Compound	Measurement	Flow rate/ Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
CO	EC4-500-CO Electrochemical cell	0.5-1.0 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or new sensor	Data stored on external hard drive

B2.4. NO Measurements

The NO sensor (NO-D4) is an electrochemical gas sensor (Alphasense, Essex, United Kingdom) which measures NO concentration by means of an electrochemical. The NO-D4 sensor has a NO detection range of 0 to 100 ppm with resolution of < 0.1 RMS noise (ppm equivalent) and linearity of <±1.5 ppm error at full scale. The NO-D4 has a T-95 response time of <15 seconds (6.3±0.52 seconds measured at the EPA laboratory). The temperature and RH operating range is 0 to +50 °C and 15 to 90% RH, respectively. The NO-D4 sensor will be calibrated for NO on a daily basis in accordance with U.S. EPA Method 7E [3]. Calibration details are described in Section B7. The NO-D4 NO concentration will be recorded on the Teensy a USB-based microcontroller board using an Arduino-generated data program. NO background samples will be taken daily prior to sampling.

Table B2.5: NO Measurements.

Target Compound	Measurement	Flow rate/ Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
NO	NO-D4 Electrochemical cell	0.5-1.0 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or new sensor	Data stored on external hard drive

B2.5. NO_2 Measurements

The NO_2 sensor (NO2-D4) is an electrochemical gas sensor (Alphasense, Essex, United Kingdom) which measures NO_2 concentration by means of an electrochemical cell. The NO2-D4 sensor has a NO_2 detection range of 0 to 10 ppm with resolution of < 0.1 RMS noise (ppm equivalent) and linearity error of -0.6-0 ppm. The NO2-D4 has a T-95 response time of <35 seconds (32.3±3.8 seconds measured at the EPA laboratory). The temperature and RH operating range is 0 to +50 °C and 15 to 90% RH, respectively. The NO2-D4 sensor will be calibrated for NO_2 on a daily basis in accordance with U.S. EPA Method 7E [3]. Calibration details are described in Section B7. The NO2-D4 NO_2 concentration will be recorded on the Teensy a USB-based microcontroller board using an Arduino-generated data program. NO background samples will be taken daily prior to sampling.

Table B2.6: NO_2 Measurements.

Target Compound	Measurement	Flow rate/ Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
NO_2	NO2-D4 Electrochemical cell	0.5-1.0 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or new sensor	Data stored on external hard drive

B2.6. Total Hydrocarbon

The Ion Science (Cambridge, United Kingdom) MiniPID2 photoionization detector will be used for measuring THC. The detection limit ranges from 0-100 ppm with a rapid response time of 3 seconds and a resolution of 5 ppb. The temperature and RH operating range is -40 to 65 °C and 0 to 99% RH, respectively. The sensor board enables the user to set the max output current (20mA) to a user set span concentration as long as the span point is less than the maximum range of the sensor.

The MiniPID2 will be calibrated on a daily basis in accordance with EPA Method 3A [2]. Calibration details are described in Section B7. If the calibration is outside the acceptance criteria (Table B2.3) the first corrective action will be to re-calibrated the MiniPID2 and the second step is to replace it with another MiniPID2. Data will be recorded on the Teensy, a USB-based microcontroller board using an Arduino-generated data program.

Table B2.7: THC Measurements.

Target Compound	Measurement	Flow rate/ Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
THC	MiniPID2 Electrochemical cell	0.3-0.5 L/min, every second	3 point calibration	±5% of cal gas	Re-calibrate or new sensor	Data stored on external hard drive

B2.7. $PM_{2.5}$ Measurements

PEM

IMPACT sampler and Leland Legacy

The Kolibri will be sampling $PM_{2.5}$ with SKC Personal Environmental Monitor (PEM) impactors (SKC Inc., PA USA) using 37 mm tared Teflon® filter with a pore size of 2.0 µm via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 10 L/min. Particles larger than 2.5 µm in the $PM_{2.5}$ impactor will be collected on an oiled impaction disc mounted on the top of the filter cassette.

The Flyer will be sampling $PM_{2.5}$ and PM_{10} with SKC IMPACT sampler (SKC Inc., PA USA) using 47 mm tared Teflon® filters with a pore size of 2.0 µm via a Leland Legacy sample pump (SKC Inc., USA) with a constant airflow of 10 L/min. Particles larger than 2.5 µm in the $PM_{2.5}$ impactor and larger than 10 µm in the PM_{10} impactor will be collected on an oiled 37 mm impaction disc mounted on the top of their respective filter cassettes.

The 37 mm Teflon® filters to be used for the $PM_{2.5}$ samples will be obtained pre-weighed from Chester LabNet. The Teflon® filters will be inspected for tears and contamination prior to placing them into the impactors (Table B2.8). After sample collections the sampled filters are returned to the filters' petri-dish (labeled with Filter ID and Lab ID) and sealed with Teflon® tape. The petri-dishes are stored in separate labeled Zip-Lock bags. The Zip-Lock bags will be labeled with the sampling information e.g. impactor number, filter ID, Lab ID, sampling date, run number, and test configuration. Filter samples are shipped to Chester LabNet for post-weighing. $PM_{2.5}$ and PM_{10} filters will be analyzed for composition using X-Ray Fluorescence (XRF) by Chester LabNet following EPA compendium method IO-3.3 using current XRF technology. Samples will also be analyzed by Inductively coupled Plasma Mass Spectrometry (ICP-MS) following EPA Method 6020 in the CEMM ICP-MS Class 100 Clean Lab in D456 on the RTP campus.

The 47 mm Teflon® filter samples will be used for toxicity testing and the teflon filters will be measured gravimetrically using an analytical balance at ORD. The $PM_{2.5}$ 47 mm filters will be stored in a thermally insulated cooler box (<4°C) until transferred to Dr. Gilmour.

Table B2.8: $PM_{2.5}$ Batch Measurements.

Target Compound	Measurement	Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling	Hold time
$PM_{2.5}$	SKC Personal Environmental Monitor impactor, Sensidyne pump, Teflon® filter	10 L/min	Gas pump flow calibration with Go-cal, filter inspection	±5% of 10 L/min, no tear in filter	Re-calibrate gas pump, replace pump, replace filter	1 filter in one petri dish/sample	30 days
$PM_{2.5}$	SKC IMPACT Sampler, Leland Legacy pump, Teflon® filter	10 L/min	Gas pump flow calibration with Go-cal, filter inspection	±5% of 10 L/min, no tear in filter	Re-calibrate gas pump, replace pump, replace filter	1 filter in one petri dish/sample, store at <4°C	30 days
PM_{10}	SKC IMPACT Sampler, Leland Legacy pump, Teflon® filter	10 L/min	Gas pump flow calibration with Go-cal, filter inspection	±5% of 10 L/min, no tear in filter	Re-calibrate gas pump, replace pump, replace filter	1 filter in one petri dish/sample, store at <4°C	30 days

B2.8. Total PM

Total PM will be sampled onto a Teflon™ filter (20.3×25.4 cm) using a low voltage Windjammer brushless direct current blower (AMETEK Inc., USA) with a nominal sampling rate of 1.0 m^3/min. After sampling the Teflon™ filter is removed, folded into a glass jar, tagged and stored in a thermally insulated cooler box (<4°C) until transferred to USGS.

Table B2.9: Total PM Batch Measurements.

Target Compound	Measurement	Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling
Total PM	Windjammer brushless direct current blower	1.0 m^3/min	Filter inspection, gas pump flow calibration	No tear in filter, ±10%	Replace filter, re-calibrate gas pump	1 filter in one glass jar/sample, store at <4°C

B2.9. Continuous Measurements of Particulate Matter

B.2.9.1 Continuous Measurements of PM_1, $PM_{2.5}$, PM_4, and PM_{10}

Continuous PM will be sampled with DustTrak DRX 8533 and 8534, (TSI, Shoreview, MN, USA). These instruments measure light scattering by aerosols as they intercept a laser diode and have the capability of simultaneous real-time measurement (every second) of PM_1, $PM_{2.5}$, Respirable (PM_4), PM_{10}, and Total PM (up to 15 µm). The aerosol concentration range for the DustTrak

DustTrak 8533

DustTrak 8534

DRX 8533/8534 is 0.001-150 mg/m^3 with a resolution of ±0.1% of reading.

DustTrak 8533 includes an enclosed 37-mm filter cassette which provides a simultaneous total suspended particles (TSP) gravimetric sample. The total flow rate is 3 L/min where for DustTrak 8533 1/3 of the flow rate is used for the continuous measurements and 2/3 is used for the gravimetric sample. The enclosed gravimetric sample is used to conduct a PCF for the Total PM. The DustTrak DRX 8533/8534 is factory calibrated to the respirable fraction, with a PCF value of 1.00. A custom PCF is conducted as per manufacturer's recommendations for $PM_{2.5}$ using the simultaneously sampled $PM_{2.5}$ by filter impactor concentrations (averaged continuous $PM_{2.5}$ concentration divided by $PM_{2.5}$ by filter mass concentration). This factor is applied to scale the real-time data.

The 37 mm Teflon® filters will be obtained pre-weighed from Chester LabNet. The Teflon® filters will be inspected for tears and contamination prior to placing them into the filter cassettes. After sample collections the sampled filters are returned to the filters' petri-dish (labeled with Filter ID and Lab ID) and sealed with Teflon® tape. The petri-dishes are stored in separate labeled Zip-Lock bags. The Zip-Lock bags will be labeled with the sampling information e.g. impactor number, filter ID, Lab ID, sampling date, run number, and test figuration. Filter samples are shipped to the Chester LabNet for post-weighing.

Table B2.10: Continuous PM Measurements.

Target Compound	Instrument	Measurement	Concentration range	Sampling Rate	Sample Handling
Simultaneously TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1	TSI DustTrak DRX 8533/8534	Particle size distribution/ Laser Particle Counter - light scattering	0.001-150 mg/m^3	Every second, 1 L/min	Data downloaded to external hard drive
Total PM	TSI DustTrak DRX 8533	37 mm Teflon Filter	NA	2 L/min	1 filter in one Petri dish/ sample

B.2.9.2 Continuous Measurements of $PM_{2.5}$

Continuous $PM_{2.5}$ will be sampled with a SidePak™ AM520, (TSI, Shoreview, MN, USA). This instrument measures light scattering by aerosols as they intercept a laser diode and has the capability of real-time measurement (every second) of PM_1, $PM_{2.5}$, Respirable (PM_4), PM_{10}, or Total PM (up to 15 µm). For this study the SidePak™ AM520 will be configured with a $PM_{2.5}$ inlet to measure $PM_{2.5}$. The aerosol concentration range for the SidePak™ AM520 is 0.001-100 mg/m^3 with a resolution of ±0.1% of reading.

The sampling flow rate is user adjustable and will be set to 1.5 L/min. The SidePak™ AM520 is factory calibrated to the respirable fraction, with a PCF value of 1.00. A custom PCF is conducted as per manufacturer's recommendations for $PM_{2.5}$ using the simultaneously sampled

$PM_{2.5}$ by filter impactor concentrations (averaged continuous $PM_{2.5}$ concentration divided by $PM_{2.5}$ by filter mass concentration). This factor is applied to scale the real-time data.

Table B2.11: Continuous PM Measurements.

Target Compound	Instrument	Measurement	Concentration range	Sampling Rate	Sample Handling
$PM_{2.5}$	TSI SidePak™ AM520	Particle size distribution/ Laser Particle Counter - light scattering	0.001-100 mg/m^3	Every second, 1.5 L/min	Data downloaded to external hard drive

B2.10. Black Carbon

B.2.10.1 MA200 and MA350

The MA200/MA350 instruments measures BC concentrations in ng/m^3 using a calibrated filter-based light attenuation measurement, which is the same operating principle for all Aethalometers. Concentrations are measured at 5 wavelengths, ranging from 375 nm (UV) to 880 nm (IR). The unit contains an 85 sampling location automatic filter tape advance system, allowing for long-term continuous measurements without the need for repeated filter replacements. Once attenuation reaches a user-specified value, the filter cartridge automatically advances to a clean part of the filter tape. The instrument also utilizes dual-spot sampling technology [4], in which two parallel spot measurements are recorded simultaneously at varying flow rates. Based on these measurements, a real-time compensation algorithm is implemented, accounting for and correcting filter loading effects [5-7], a common Aethalometer phenomenon.

Table B2.12: MA200 and MA350 Information.

Target Compound	Measurement/Analytical Method	Sampling Rate	Measurement resolution	Measurement precision	Flow rate
Black Carbon	MA200/MA350 Change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	1-300 seconds	0.001 µg BC/m^3	±0.1 µg BC/m^3, 1 min avg., 150 mL/min flow rate	50, 100, 150 mL/min

B.2.10.2 AE51

The AE51 (Aethlabs, San Franscisco, CA USA) will serve as a backup instrument to MA200 and MA350. The AE51 is a small, portable, hand-held instrument capable of measuring BC concentration, as defined by the manufacturer. This instrument determines the BC concentration at 880 nm by absorption. The AE51 has the physical dimensions of 117 mm x 66 mm x 38 mm and weighs approximately 250 g. The AE51 instrument is capable of sampling in increments of 1, 60, or 300 seconds from 0-1 mg BC/m^3. A red-light alarm indicates when the pressure drop across the coupon is excessive, and the coupon needs to be changed out.

Table B2.13: AE51 Information.

Target Compound	Measurement/Analytical Method	Sampling Rate	Measurement resolution	Measurement precision	Flow rate
Black Carbon	AE51 Change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	1-300 seconds	0.001 µg BC/m^3	±0.1 µg BC/m^3, 1 min avg., 150 mL/min flow rate	50, 100, 150 mL/min

B2.11. Total Carbon, Organic Carbon, and Elemental Carbon

TO/OC/EC will additionally be sampled with SKC $PM_{2.5}$ personal modular impactor using 37 mm quartz filter via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 3 L/min. Particles larger than 2.5 µm in the $PM_{2.5}$ impactor will be collected on an oiled 25 mm impaction disc mounted on the top of the filter cassette.

The quartz filters have been pre-baked at ORD according to NIOSH Method 5040 [8] and stored in a thermally insulated cooler box (<4°C) during transportation and at the field site. After sample collections the sampled filters are returned to the filters' petri-dish (labeled with Filter ID). The petri-dishes are stored in separate labeled Zip-Lock bags and returned to the thermally insulated cooler box (<4°C) until transfer to the ORD Fine PM Characterization Laboratory. The Zip-Lock bags will be labeled with the sampling information e.g. impactor number, filter ID, Lab ID, sampling date, run number, and test figuration.

Table B2.14: TC/OC/EC Batch Measurements.

Target Compound	Measurement Instrument/ Parameter	Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling	Hold time
TC/OC/EC	SKC personal modular impactor, C120CNSN pump,	3 L/min	Gas pump flow calibration with Go-cal, filter inspection	±5% of 3 L/min	Re-calibrate gas pump, replace pump	Data transferred to external hard drive	NA
TC/OC/EC	Quartz filter	3 L/min	Filter inspection	No tear in filter	Replace filter	1 filter in one petri dish/	30 days

						sample, stored at <4°C	

B2.12. Volatile Organic Compounds

VOCs will be sampled using Carbotrap 300 stainless steel TD Tube (Supelco Inc., Bellefonte, PA, USA) via a constant micro air pump at 200 mL/min (3A120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) in accordance with U.S. EPA Method TO-17 [9]. The VOCs captured on the Carbopack 300 are stated in Table B2.16. The constant pump is turned off and on based on the CO_2 concentration trigger set point using the KolibriDAQ program a labview generated program on the remote computer. The trigger function is turned off when the pump can no longer maintain the set flow, which is indicated on the KolibriDAQ interface.

Table B2.15: VOC Batch Measurements.

Target Compound	Measurement	Sampling Rate	Check Procedure	Acceptance Criteria	Corrective Action	Sample Handling	Hold time
VOC	3A120CNSN Sensidyne pump	0.2 L/min	Gas pump flow calibration with Go-cal, filter inspection	±5% of 0.2 L/min	Re-calibrate gas pump, replace pump, replace tube	Data transferred to external hard drive	NA
VOC	Carbotrap 300	0.2 L/min	Tube inspection	No visible damage to tube	Replace tube	1 Carbotrap/ sample bag, stored at <4°C	30 days

Table B2.16: VOC Captured on Carbotrap 300.

VOCs		
1,1,1-Trichloroethane*	2-Hexanone	Ethanol
1,1,2,2-Tetrachloroethane*	2-Propanol (Isopropyl Alcohol)	Ethylbenzene*
1,1,2-Trichloroethane*	4-Methyl-2-pentanone	Hexachlorobutadiene*
1,1-Dichloroethane	Acetone	m,p-Xylenes*
1,1-Dichloroethene	Acetonitrile*	Methyl tert-Butyl Ether
1,2,4-Trichlorobenzene*	Benzene*	Methylene Chloride*
1,2,4-Trimethylbenzene	Bromodichloromethane	Naphthalene*
1,2-Dibromo-3-chloropropane	Bromoform*	n-Heptane
1,2-Dibromoethane	Carbon Disulfide*	n-Hexane
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	Carbon Tetrachloride*	n-Octane
1,2-Dichlorobenzene	Chlorobenzene*	o-Xylene*
1,2-Dichloroethane	Chloroethane	Styrene*
1,2-Dichloropropane	Chloroform*	Tetrachloroethene
1,3,5-Trimethylbenzene	Chloromethane*	Tetrahydrofuran (THF)
1,3-Butadiene*	cis-1,2-Dichloroethene	Toluene*

VOCs		
1,3-Dichlorobenzene	cis-1,3-Dichloropropene*	trans-1,2-Dichloroethene
1,4-Dichlorobenzene	Cumene*	trans-1,3-Dichloropropene
1,4-Dioxane	Cyclohexane	Trichloroethene
2,2,4-Trimethylpentane (Isooctane)	Dibromochloromethane	Trichlorofluoromethane
2-Butanone (MEK)*	Dichlorodifluoromethane (CFC 12)	Trichlorotrifluoroethane
		Vinyl Chloride*

* On U.S. EPA's list of hazardous air pollutants [10].

B2.13. Ozone

Ozone (O_3)will be measured using a Personal Ozone Monitor™ Model POM™ (2B Technologies Inc., Boulder, CO). The POM™ measures O_3 via UV absorption. Ozone is measured based on the attenuation of light passing through a 15-cm absorption cell with quartz windows. The POM™ has a limit of detection of 3.0 ppb and a precision and accuracy of 1.5 ppb or 2% or reading. The POM™ weighs only 340 grams and measures 10.2 × 7.6 × 3.8 cm.

Table B2.17: POM™ Information.

Target Compound	Measurement/Analytical Method	Sampling Rate	Measurement resolution	Measurement precision	Flow rate
O_3	MA200/MA350 Change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	2 or 10 seconds	3 ppb	± 1.5 ppb or 2% of reading	0.8 L/min

B2.14. Weather Station and Weather Meter

A Davis Vantage Vue wireless weather station (Davis Instruments Corporation, Hayward, CA USA) will be placed upwind of burn plots if possible to measure ambient conditions such as temperature, wind speed, wind direction, RH, and barometric pressure.

Davis Vantage Vue

Kestrel Weather Meter

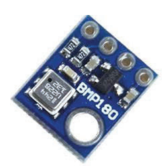
Kestrel Weather meters 450 and 550 Fire Weather Pro (KestrelMeters, Boothwyn, PA USA) will also be placed around the burn plots to measure ambient conditions such as temperature, wind speed, RH, and barometric pressure.

Table B2.18: Weather Station and Weather Meter Information.

Measured Parameter	Instrument	Range	Accuracy	Operating Temperature Range	Data logging
Relative Humidity	Davis Vantage Vue	1-100% RH	±2% RH	-40 to 65°C	1 minute
Temperature	Davis Vantage Vue	-40 to 65°C	±0.5°C >-7°C	-40 to 65°C	1 minute
Barometric Pressure	Davis Vantage Vue	410-820 mm Hg	±0.8 mm Hg	-40 to 65°C	1 minute
Wind Speed	Davis Vantage Vue	0 to 89 m/s	1 m/s or ±5% of reading	-40 to 65°C	1 minute
Wind Direction	Davis Vantage Vue	1-360°	±3%	-40 to 65°C	1 minute
Relative Humidity	Kestrel 450, 550	10-90% RH	±2% RH	-10 to 55°C	2 seconds to 12 hours
Temperature	Kestrel 450, 550	-20 to 70 °C	±0.1°C	-10 to 55°C	2 seconds to 12 hours
Barometric Pressure	Kestrel 450, 550	750-1100 Pa	±1.5 hPa	-10 to 55°C	2 seconds to 12 hours
Wind Speed	Kestrel 450, 550	0.6 to 40.0 m/s	±3% of reading	-10 to 55°C	2 seconds to 12 hours

B2.15. Other Measurements

The Kolibri is also equipped with a temperature and barometric pressure sensor (BMP 180, Adafruit, New York, USA), a GPS sensor (Ultimate GPS Breakout V3, Adafruit, New York, USA) and RH sensor (Adafruit DHT22, Adafruit, New York, USA) as summarized in Table B2.19.


BMP 180


GPS Breakout V3


DHT22

Table B2.19: GPS, Pressure, and Temperature Sensors.

Target	Sensor	Sampling Rate	Range	Accuracy
Temperature	BMP 180	Every second	-25 to 85°C	±2°C
Barometric pressure	BMP 180	Every second	300-1100 hPa	0.03 hPa resolution
GPS	Ultimate GPS, Breakout V3	Every second	Velocity: 515 m/s	Position: < 3m Velocity: 0.1 m/s
Relative Humidity	Adafruit DHT22	0.5 hz	0-100%	±5%

B3. Sample Handling and Custody

B3.1. Sample Identification

Each test will be designated a run number and given an identifying code number. The codes and code sequence will be explained to the sampling team and laboratory personnel to prevent sample mislabeling. Each sample will be given a sample identification (ID) number as described in Table B3.1. A label with the designated sample ID will be attached to each of the samples. Proper application of the code will simplify sample tracking throughout the collection, handling, analysis, and reporting processes.

The run number, matrix, start and stop time, raw data logging file name, sample ID, filter ID, and impactor number for each test will be recorded on a Sampling Record form (Figure B3.1). Sample CoC forms (Figure B3.2) will be initiated and maintained by Dr. Aurell. For each collected target material sample, a CoC sheet will be generated.

The data sets and all derivative data sets will be retained by Dr. Gullett. All primary and secondary data will be retained in duplicate by Dr. Brian Gullett on the L drive on the EPA network (L:\Lab\NRMRL_Aurell\ Tallgrass and Konza Prairie\2021) to preserve all of the raw data files collected and separately store any copies and/or derivative files in sub folders. The Sampling Record forms and CoCs will be scanned and stored electronically as portable document format (PDF) files in L:\Lab\NRMRL_Aurell\Tallgrass and Konza Prairie\2021\CoC.

Table B3.1: Sample Nomenclature

AA-BB-CC-MMDDYY-DD-EE		
	Sample Code	Code definition
AA	PS	Test Condition (TB = Trip blank, PS = Plume Sample, BS = Background Sample)
BB	PM2.5	Sampling Media (PM2.5 = Particulate Matter Filter, DustTrak)
CC	OB1	Field Site Number (OB - operational burn, SP – small plot)
MMDDYY	071520	Date Field, month/day/year
DD	K	Sampler used (K = Kolibri)
EE	01	Sample Number (01, 02, 03, etc.)

SAMPLING RECORD

Project name:
Project location:

Matrix: ______ Start time: ______

Date: ______ Stop time: ______

☐ CO_2 ☐ SVOC Sorbent pack ☐ Black Carbon - Aeth.

☐ CO ☐ $PM_{2.5}$ Quartz filter ☐ PM_{10}

☐ ☐ 6 L Summa Canister ☐ $PM_{2.5}$ Teflon filter

☐ GPS, MTiG ☐ ☐ Continuous PM

CO_2 trigger concentration (ppm):
Ambient temperature (°C):
Ambient pressure:

SVOC Sorbent pack
Sample ID:
Venturi #:

$PM_{2.5}$ Teflon filter
Sample ID:
Lab filter ID:
Impactor #:

6 L Summa Canister
Sample ID:
CAS Lab #:
Filter pore size:

$PM_{2.5}$ Quartz filter
Sample ID:
Lab filter ID:
Impactor #:

PM_{10}
Sample ID:
Lab filter ID:
Impactor #:

Black Carbon - Aeth.
Sample ID:
Start:
Stop:

Sample ID:
Filter #1:
Filter #2:
Filter #3:

Continuous PM
Data file name:

LabView Data file names:

Comments:

Figure B3.1: Example of a Sampling Record Form.

Project: **CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM** Page of

SAMPLER:

Requested Analyses

SAMPLE ID	DATE	TIME	MATRIX	PM	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks

Requested Analyses	
1	
2	
3	
4	
5	
6	
7	

Special Instructions/Comments: ☐ **Special QA/QC Instructions**

Laboratory Information and Receipt

Lab Name:
Shipping Tracking #
Specify Turnaround Requirements:
☐ Cooler packed with ice
☐ Cooler custody seal intact
Sample Receipt:
Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:

Figure B3.2: Example of a Chain of Custody Form.

B4. Analytical Methods

B4.1. Summary of Analytical Methods

Table B4.1 shows a summary of the analytical methods used in the study and the laboratories conducting the analyses.

Table B4.1: Summary of Analytical Methods.

Analyte	Instrument/ Equipment	Method	Analytical Method	Lab.
CO_2	LICOR-820, K30	NDIR	NA	NA
CO	EC4-500-CO	Electrochemical cell	NA	NA
NO	NO-D4	Electrochemical cell	NA	NA
NO_2	NO2-D4	Electrochemical cell	NA	NA
O_3	POM™	UV absorption	NA	NA
$PM_{2.5}$	SKC Personal Environmental Monitor Sampler	Teflon® filter/gravimetric	40 CFR Part 50 Appendix L [11]	Chester LabNet, ORD/CEMM
$PM_{2.5}$	SKC IMPACT Sampler	Teflon® filter/gravimetric	40 CFR Part 50 Appendix J [11]	ORD/CPHEA
PM elemental composition	SKC Impact Sampler	Teflon® filter/gravimetric	EPA compendium method IO-3.3., EPA Method 6020	Chester LabNet ORD/CEMM
PM by size	DustTrak DRX 8533	Teflon® filter	40 CFR Part 50 Appendix J, L [11, 12]	Chester LabNet
PM by size	DustTrak DRX 8533/8534, SidePak AM520	Light attenuation	NA	NA
TC/OC/EC	SKC Personal Modular Impactor	Quartz Filter	Modified NIOSH Method 5040 [8] and Khan et al. [13]	EPA CEMM
VOC	Sorbent tube	CarboTrap 300	TO-17 [9]	ALS California
BC	MA200/MA350	Light attenuation	NA	NA

NA = not applicable (continuous measurements).

B4.2. PM Mass Analytical Method

The 37 mm Teflon® filters will be obtained pre-weighed from Chester LabNet. Chester LabNet will post-weigh the filters collected from $PM_{2.5}$ impactors and cassettes used by the DustTrak DRX 8533 according to 40 CFR Part 50 Appendix J and L [11, 12] .

The 47 mm Teflon® filters and 37 mm Teflon® filters will be pre- and post-weighed by EPA/ORD/CPHEA and EPA/ORD/CEMM laboratories, respectively, following procedures in 40 CFR Part 50 Appendix J and L [11, 12]. The analytical balance used to weigh filters shall be suitable for weighing the type and size of filters and have a readability of ±10 µg. All sample filters used shall be conditioned to 20-23 °C and 30-40 % RH for a minimum of 24 h immediately before both the pre- and post-sampling weighing. Both the pre- and post-sampling weighing should be carried out on the same analytical balance, using an effective technique to neutralize static charges on the filter. The post-sampling conditioning and weighing shall be completed within 30 days after the end of the sample period.

B4.3. Elemental Composition

$PM_{2.5}$ and PM_{10} filters will be analyzed for composition using X-Ray Fluorescence (XRF) by Chester LabNet following EPA compendium method IO-3.3 using current XRF technology[14]. Samples will also be analyzed by Inductively coupled Plasma Mass Spectrometry (ICP-MS) by CEMM ICP-MS Class 100 Clean Lab in D456 on the RTP campus according to "Extraction of Filter Media for Ion Chromatography and High Resolution Inductively Coupled Plasma Mass Spectrometry" Standard Operating Procedures (J-WECD-MMB-SOP-1404-0) and analyzed according to "Standard Operating Procedure for Operation and Maintenance of the Element 2 High-Resolution Inductively Coupled Plasma Mass Spectrometry Instrument," in accordance with EPA Method 6020[15].

B4.4. Organic Carbon, Elemental Carbon, and Total Carbon Analytical Methods

The TC/OC/EC will be analyzed at EPA/ORD/CEMM using a modified thermal-optical analysis (TOA) using Modified NIOSH Method 5040 [8] and Khan et al. [13]. The pre-baked quartz filters should have less than 0.1 µg OC residuals per cm^2 according to NIOSH Method 5040 [8]. The analyses should be completed within 30 days after the end of the sample period.

B4.5. VOC Analytical Method

The Carbotrap 300 will be analyzed by ALS Simi Valley CA for VOCs by thermal desorption gas chromatography/mass spectrometry (GC/MS) according to U.S. EPA Method TO-17 [9]. This method is included on ALS's NELAP and DoD-ELAP scope of accreditation. The analyses of the Carbotrap shall be completed within 14 days after the end of the sample period.

B5. Quality Assurance/Quality Control

B5.1. Quality Assurance/Quality Control Information for Laboratory

Table B5.1 summarize the QA/QC for each instrument/equipment conducted in the field. Instrument/equipment used by external laboratories are not included in this QAPP.

The gas sensors (CO, CO_2, NO, NO_2, THC) will be checked daily by conducting a three-point calibration using certified calibration gases (see Section B7). All pumps used for collection will have their pump flows calibrated before the study and checked daily during the study. DustTrak DRX 8533/8534 and SidePak AM520 will be checked daily using zero filters. Background levels will be measured before each burn for CO_2, CO, NO, NO_2, THC, BC, O_3 and continuous PM. One VOC background sample will be sampled during the field effort.

Table B5.1: Quality Assurance/Quality Control Information.

Target Compound	Instrument/ Equipment	QA/QC Check Procedure	Acceptance Criteria/DQIs	Reference Standard	Corrective Action
CO_2	LICOR-820, K30	3 point zero & calibration drift test	±5% of span	Certified CO_2 calibration gases	Re-calibrate, replace LICOR
CO	EC4-500-CO	3 point zero & calibration drift test	±5% of span	Certified CO calibration gases	Re-calibrate sensor, replace sensor
NO	NO-D4	3 point zero & calibration drift test	±5% of span	Certified NO calibration gases	Re-calibrate sensor, replace sensor
NO_2	NO2-D4	3 point zero & calibration drift test	±5% of span	Certified NO_2 calibration gases	Re-calibrate sensor, replace sensor
THC	MiniPID2	3 point zero & calibration drift test	±5% of span	Certified Isobutylene calibration gases	Re-calibrate sensor, replace sensor
$PM_{2.5}$	C120CNSN Micro Pump	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
TC/OC/EC	C120CNSN Micro Pump	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
$PM_{2.5}$ and PM_{10}	Leland Legacy Pump	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
Total PM	Windjammer brushless direct current blower	Gas pump flow calibration with roots meter	±10% of flow rate	Roots meter	Re-calibrate pump, replace pump
VOC	3A120CNSN Micro Pump	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
Particle Size Distribution	DustTrak DRX 8533/8534, SidePak AM520	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Check for leaks or obstructions in the inlet, re-calibrate pump, replace filter, follow manufacturers procedures
Particle Size Distribution	DustTrak DRX 8533/8534, SidePak AM520	Zero check, daily	±0.005 mg/m^3	Zero filter	Check for leaks or obstructions in the inlet, re-calibrate pump, replace filter, follow manufacturers procedures, replace DustTrak
Black Carbon	MA200/MA350, AE51	Pump flow calibration with Go-cal, prior to testing	±5% of flow rate	Go-cal air flow calibrator	Check for leaks or obstructions in the inlet, re-calibrate pump, follow manufacturers procedures

Table B5.2. In Laboratory Quality Assurance/Quality Control Information.

Target Compound	Instrument/ Equipment	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Reference Standard	Corrective Action
Particulates, Elements	Filter blanks	Blank filter check before and after field effort	±30 ug	Filter blank	Re-calibrate balance
TC/OC/EC	Method blanks	Blank quartz filter, repeat analyze of same filter	Method blank <0.1 µg C/cm2, ±15%	Blank quartz filters, repeat of sample filter	Redo method blank or complete an oven bakeout, re-analyze sample; check calibration precision

B5.2. Data Variability

Replicate test data will be compared by means and standard deviations (Stand. Dev.) or relative percent difference (RPD) when only two values are known. Standard deviation, relative standard deviation (RSD), and RPD are measures of dispersion, calculations shown in Equations 1 to 3.

$$Standard\ Deviation = \sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}} \qquad \textit{Equation 1}$$

where:
x = each sample value
$\bar{x}$ = mean value of samples
n = number of samples

$$RSD\ (\%) = 100 \times \frac{Standard\ Deviation}{Sample\ Average} \qquad \textit{Equation 2}$$

$$RPD\ (\%) = 100 \times \frac{x_1 - x_2}{\frac{x_1 + x_2}{2}} \qquad \textit{Equation 3}$$

where:
x_1 = sample value one
x_2 = sample value two

B5.3. Data Analysis

The emission ratio of each species of interest will be calculated from the ratio of pollutant concentrations to background-corrected CO_2 and CO concentrations. Emissions factors for all targets will be calculated using these emissions ratios following the carbon balance method (Burling et al. [16]), shown in Equation 4.

$$EF_i = f_c \frac{ER_i}{\sum_j \frac{\Delta C_j}{\Delta CO_2 + \Delta CO}} \qquad \textit{Equation 4}$$

where EF_i is the emission factor of species i in terms of gram effluent per kilogram fuel, f_c is the fraction of carbon in the fuel, ER_i is the mass emission ratio of species i, ΔCO_2 is the background-corrected mass concentration of CO_2, ΔCO is the background-corrected mass concentration of CO, ΣC_j is the background corrected mass concentration of carbon in major carbon emissions species j. The majority of the carbon emissions will be emitted as CO_2.

Replicate test data will be compared by means and RSDs (or RPD when only two values are known). These measurements have not previously been made but a reasonable RSD/RPD might be ±50%.

B6. Instrument/Equipment Testing, Inspection, Maintenance

All instruments will be checked to make sure they are operational before leaving the laboratory for the field. The following spare instruments/equipment will be available

- Kolibri system
- Flyer system
- LICOR-820
- CO_2 Engine® K30 FR
- e2V EC4-500-CO, CO sensors
- NO-D4, NO sensors
- NO2-D4, NO_2 sensors
- MiniPID2, THC sensor
- Micro air pumps, C120CNSN, A3C120CNSN
- Leland Legacy pump
- DustTrak DRX 8533
- SidePak™ AM520
- Kestrel 450
- Go-Cal calibrator
- Panasonic Toughbook
- Panasonic Toughpad
- Dell Toughbook
- Dell Toughpad

Spare parts will include regulators, tubing, tube fittings, batteries (AA, AAA, 9V, CR230), teensy computers, and Kolibri parts. Dr. Aurell will be responsible to check that instruments on the Kolibri and Flyer are in working order.

B7. Instrument/Equipment Calibration Frequency

Table B7.1 and Table B7.3 summarizes the calibration frequency of instruments/equipment used in the field and laboratory, respectively. Instrument/equipment used by external laboratories are not included in this QAPP.

Table B7.1: Calibration Frequency and QA/QC for Instrument/Equipment.

Target Compound	Instrument/ Equipment	QA/QC Check Frequency	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Reference Standard	Corrective Action
CO_2	LICOR-820	Daily in field	3 point zero & calibration drift test	±5% of span	Certified CO_2 calibration gases	Re-calibrate, replace LICOR
CO	EC4-500-CO	Daily in field	3 point zero & calibration drift test	±5% of span	Certified CO calibration gases	Re-calibrate sensor, replace sensor
NO	NO-D4	Daily in field	3 point zero & calibration drift test	±5% of span	Certified NO calibration gases	Re-calibrate sensor, replace sensor
NO_2	NO2-D4	Daily in field	3 point zero & calibration drift test	±5% of span	Certified NO_2 calibration gases	Re-calibrate sensor, replace sensor
THC	MiniPID2	Daily in field	3 point zero & calibration drift test	±5% of span	Certified Isobutylene calibration gases	Re-calibrate sensor, replace sensor
O_3	POM	Yearly	Zero air Ozone generator	±5% of span	Primary ozone standard	Follow manufacturers procedures
$PM_{2.5}$	C120CNSN Micro Pump	Daily in field	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
$PM_{2.5}$ and PM_{10}	Leland Legacy Pump	First day of sampling and 1x during sampling trip	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
Total PM	Windjammer brushless direct current blower	Once per year	Gas pump flow calibration with roots meter	±10% of flow rate	Roots meter	Re-calibrate pump, replace pump
OC/EC/TC	C120CNSN Micro Pump	Daily in field	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
VOC	3A120CNSN Micro Pump	Daily in field	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Re-calibrate pump, replace pump
Particle Size Distribution	DustTrak DRX 8533/8534, SidePak AM520	Daily in field	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Check for leaks or obstructions in the inlet, re-calibrate pump, replace filter, follow manufacturers procedures
BC	MA200/MA350, AE51	Daily in field	Gas pump flow calibration with Go-cal	±5% of flow rate	Go-cal air flow calibrator	Check for leaks or obstructions in the inlet, re-calibrate pump, follow manufacturers procedures
Weather Station	Davis Vantage Vue	Every two years	Comparison tests	±2% of reading	Calibration certified NIST traceable	Follow manufactures procedures
Weather Meter	Kestrel 450, 550	Every two years	Comparison tests	±2% of reading	Calibration certified NIST traceable	Follow manufactures procedures

The LICOR-820, K30, EC4-500-CO, NO-D4, NO_2-D4 and MiniPID2 sensors will be calibrated on a daily basis in accordance with U.S. EPA Method 3A, 10A, 7E [2, 3, 17]. All gas cylinders used for calibration are certified by the suppliers that they are traceable to NIST standards, see Table B7.2.

The C120CNSN, 3A120CNSN micro pumps, and Leland Legacy pump used to collect $PM_{2.5}$, TC/OC/EC and VOCs, respectively will be calibrated with a Sensidyne Go-Cal air flow calibrator (Sensidyne LP, USA) prior to testing and checked daily. The DustTrak DRX 8533/834, SidePak AM520, MA200/350 and AE51 will be calibrated daily with a Sensidyne Go-Cal air flow calibrator (Sensidyne LP, USA). The Windjammer brushless direct current blower used to sample for total PM is and the POM for measuring O_3 are calibrated yearly by EPA's metrology laboratory.

Table B7.2: Calibration Gas Concentrations.

Calibration gas	Concentration ppm	Vendor
CO_2	6000, 1000, 400	CalgasDirect
CO	100, 50, 10, 0	CalgasDirect
NO	40, 2, 0	CalgasDirect
NO_2	10, 2, 0	CalgasDirect
Isobutylene	5	Airgas
Isobutylene	10	Airgas

Table B7.3: Calibration Frequency and QA/QC for Instrument/Equipment Verifications in the Laboratory.

Target Compound	Instrument /Equipment	QA/QC Check Frequency	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Reference Standard	Corrective Action
Flow calibrator	Go-cal calibrator	Annually	EPA Metrology lab	±2% or reading or 0.005 L/min	MOLBLOC/MOLBOX Flow Meter Calibrator System	Repeat calibration, send to manufacturer for factory calibration
Particle Size Distribution	DustTrak DRX 8533/8534, SidePak AM520	Permanent unless damaged	Factory calibration	Per manufacturer's recommendations	Precision beads	Manufacturer's re-calibration

B8. Inspection/Acceptance of Supplies and Consumables

Table B8.1 lists the critical supplies, the vendor/laboratory, the persons responsible for the availability of those supplies, and the acceptance criteria.

Table B8.1: Critical Supplies.

Supplies/Consumables	Vendor/Lab	Acceptance Criteria	Responsible Person
CO, CO_2, NO, and NO_2 calibration gases	CalgasDirect	$\leq \pm$ 2%	Dr. Aurell, Dr. Gullett
Isobutylene calibration gases	Airgas	$\leq \pm$ 2%	Dr. Aurell, Dr. Gullett
Carbotrap 300	ALS, California	No visible breakage	Dr. Aurell, Dr. Gullett
37 mm Teflon Filters, pre-weighed	Chester LabNet, EPA/ORD/CEMM	No tears or visible contamination	Dr. Aurell, Dr. Gullett
47 mm Teflon Filters, pre-weighed	EPA/ORD/CPHEA	No tears or visible contamination	Dr. Aurell, Dr. Gullett
Teflon Filters 20.3×25.4 cm	TISCH Scientific	No tears or visible contamination	Dr. Aurell, Dr. Gullett
Baked Quartz filter	EPA/ORD/CEMM	OC < 0.1 $\mu g/cm^2$	Dr. Aurell, Dr. Gullett
Filter tapes/tickets (MA200, MA350 and AE51)	Aethlabs	No tears or visible contamination	Dr. Aurell, Dr. Gullett, Dr. Holder

B9. Non-direct Measurements

No non-direct measurements will be used in this study.

B10. Data Analysis and Management

Figure B10.1 illustrates the data management process and the storage of the generated documents in this study.

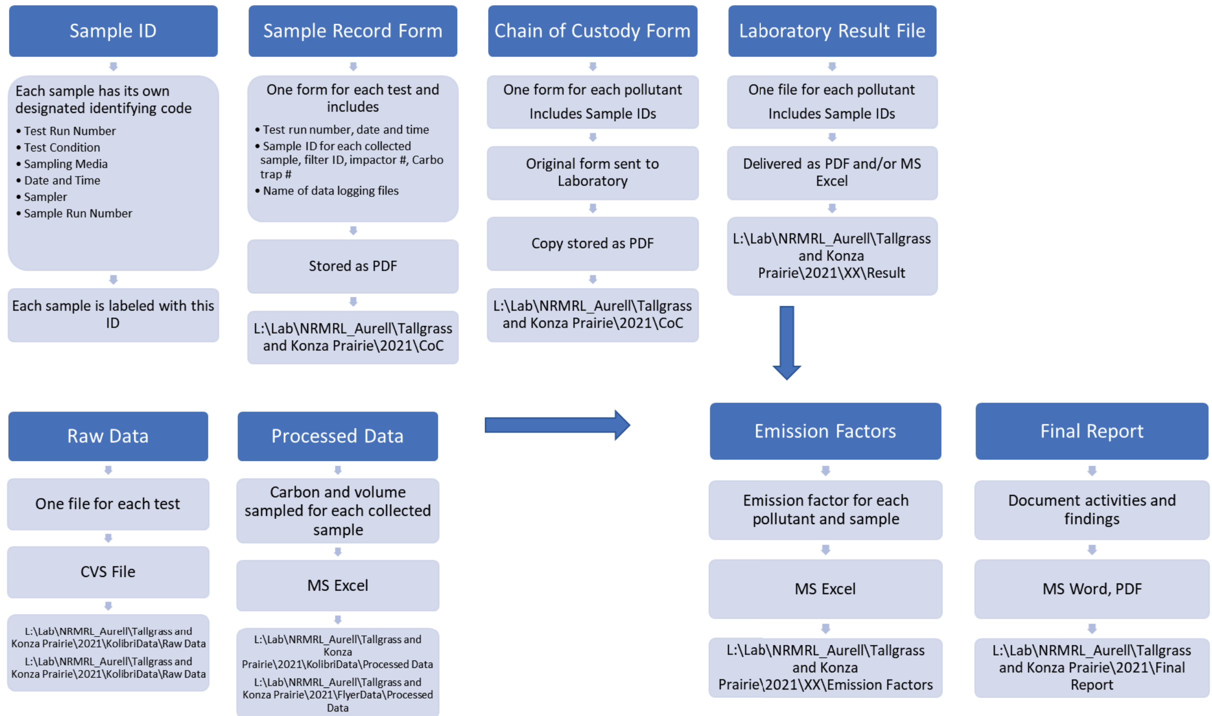


Figure B10.1: Data Management Process Flow.

C. ASSESSMENTS AND OVERSIGHT

This project does not require planned technical systems and performance evaluation audits. However, should deficiencies be identified by any of the key individuals responsible, the EPA PI will discuss the problem and corrective actions to be taken for subsequent sampling or analyses.

D. DATA VALIDATION AND USABILITY

Reporting

- An outside laboratory (ChesterLabNet) will determine mass on Teflon® $PM_{2.5}$ filters.
- An outside laboratory (ALS, California) will analyze the Carbotrap 300 for VOCs.
- Dr. Aurell will coordinate external analyses, review the methods/data.
- Dr. Aurell will calculate cumulative CO and CO_2 values relative to sampling times and then determine emission factors.

The product output of this effort will include an ORD a report for the RARE Region 7 project, and a joint EPA/USGS report.

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